ASD TECHNICAL REPORT 61-329

URINE COLLECTION AND DISPOSAL DEVICE FOR PRESSURE SUIT

ROBERT J. REDDEN

INTERNATIONAL LATEX CORPORATION

AUGUST 1961

CONTRACT No. AF 33(616)-7344

LIFE SUPPORT SYSTEMS LABORATORY
AEROSPACE MEDICAL LABORATORY
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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URINE COLLECTION AND DISPOSAL DEVICE FOR PRESSURE SUIT

ROBERT J. REDDEN

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CONTRACT MONITOR: J. D. BOWEN
CONTRACT No. AF 33(616)-7344
PROJECT No. 7164
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LIFE SUPPORT SYSTEMS LABORATORY
AEROSPACE MEDICAL LABORATORY
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

This report describes the research and development by International Latex Corporation, Dover, Delaware, of a device to collect and remove urine from a full pressure suit, sample the urine, and allow for disposal of the urine in any manner seen fit. It is the final report on this program conducted under the provisions of Contract No. AF 33(616)-7344, under Project No. 7164, "Physiology of Flight," Task No. 71831, "Personal Protection for Extreme Altitude Operations."

Mr. J. D. Bowen, Chief, Altitude Protection Section, Life Support Systems Laboratory, Aerospace Medical Laboratory, Aeronautical Systems Division, served as contract monitor.

Mr. Robert J. Redden, Project Engineer, Industrial Products Division, International Latex Corporation, was in charge of the development, fabrication, and preliminary testing of the device, and is the author of this report. Mr. Rodney Hill, Industrial Products Division, International Latex Corporation, supervised the fabrication and testing of the system.

ABSTRACT

The design, fabrication, and testing of a urine collection and disposal system, to provide a means to remove urine from within a full pressure suit during long periods of use, in a weightless environment, and to provide a means of sampling each individual specimen of urine, are discussed. The prototype system consists of three basic parts: (1) a urinal to collect the urine within the suit, (2) a valve to allow removal of the urine from the suit, and (3) a collecting bag with valving to provide for disposal of the urine. The testing program provides a means of checking conformance to the design objectives as far as possible in the presence of gravity. Tests were performed both with and against gravity. Some of the components, designed for optimum performance in a weightless condition, could be adequately tested only under that condition. Weightless tests have not been conducted.

PUBLICATION REVIEW

Wayne H. McCandless

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SECTION 1

INTRODUCTION

Background

The need for a special urine collection and disposal device for extraterrestrial flight is brought about because of the abnormal conditions that will be encountered during such flight. These are (1) weightlessness, (2) very low ambient air pressure, and (3) the enclosure of the astronaut in a full pressure suit. The collection and disposal system was designed with these conditions in mind.

The general design features required in the device were:

1. Compatibility with space suits.

2. Fabrication from material non-irritating to normal skin.

3. Comfort.

4. Protection of body parts from urine contamination.

5. Operation for periods of up to 72 hours, allowing for collection, sampling and disposal of urine outside the suit.

6. The capability of withstanding the wear and tear of normal body articulation.

7. Minimum flow of 2 liters/minute from the suit.

The effects of the abnormal conditions present in extraterrestrial flight result in certain design limitations, such as:

1. Liquids must be contained because weightlessness makes it impossible to control any free liquid in the vehicle.

2. Personnel safety does not permit opening of the suit in order to don a urinal during the course of the mission.

After the program was begun, another design limitation was found, namely: it was not possible to keep some air from mixing with the urine as it leaves the suit.

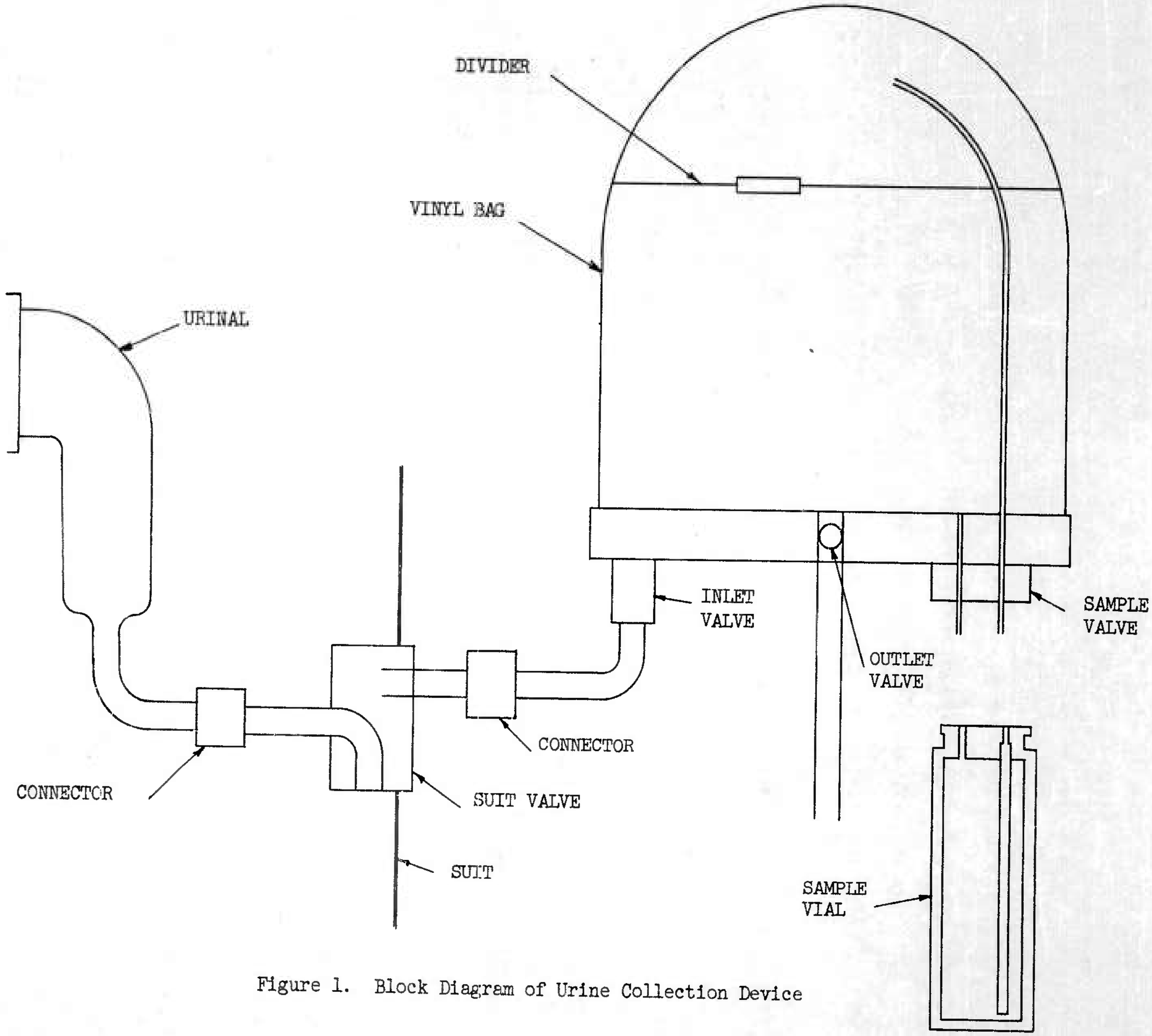

Figure 1. Block Diagram of Urine Collection Device

SECTION 2

SYSTEM DESIGN AND FABRICATION

Operating Sequence

The general layout of the urine collection and disposal system, Figure 1, was decided upon based on the design parameters and limitations set forth in the introduction of this report.

The urinal will be donned as the first step in the full pressure suit dressing sequence. It will be fed out through a hole in the crotch of the underwear, Figure 2. The suit valve is permanently attached to the suit. The urinal and suit valve will be connected after the suit is donned, prior to final closure, Figure 3. These two units will be the only portions of the device worn at all times during the flight.

The urine collection bag, with its attached valves and suit valve connector, will be stored in a container along with the sample vials until the vehicle is in orbit. The collecting bag and valves will be removed from the container, and attached to a bracket inside the cabin for use. It will be removed and restored in the container for re-entry.

Figure 2. Urinal in Place Prior to Donning Suit

The urination procedure will be as follows:

1. Connect the suit valve connector to the suit valve.
2. Open the suit valve by depressing the flat surface of the connector.
3. Urinate.
4. Release the connector to close the suit valve when all the urine has been extracted from the suit. This will be signaled by the urinal collapsing against the penis because of the differential between suit and ambient air pressure. Closing the suit valve will allow suit air back into the urinal, thus relieving pressure.
5. The urine will be forced into the collection bag by the action of inertia developed in the urine as it leaves the suit, and the differential pressure between the suit and collecting bag. Once in the bag, the urine is retained by the inlet check valve.

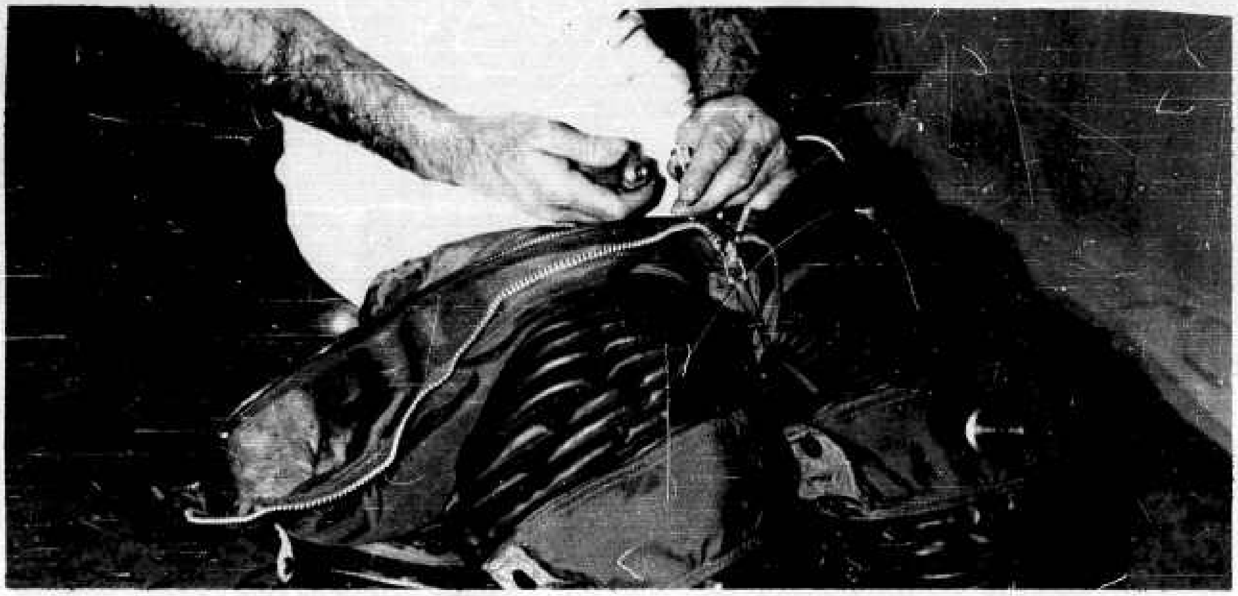

Figure 3. Connecting Urinal to Suit Valve During Suit Donning Sequence

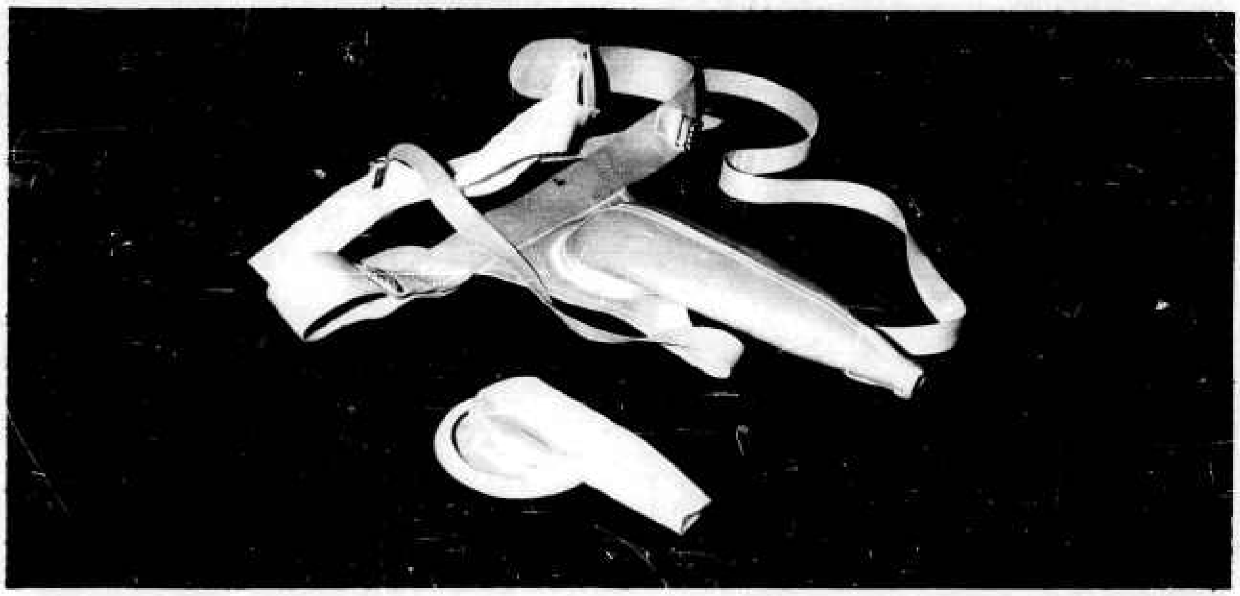

Figure 4. Urinal Disassembled Showing Inner Seal, Chamber and Securing Straps

6. The urine sample, approximately $\frac{1}{2}$ ounce, will be taken by connecting a sample vial to the sample valve and manually squeezing the collection bag.

7. The urine will be removed from the bag by opening the exhaust valve, and again squeezing the collection bag until it is emptied of both liquid and air.

Urinal

The market was surveyed for a suitable urinal among those commercially available to persons with impaired bladder control and persons who must go for long periods without access to more conventional urinals (policemen, etc.). Several groups have been working on urinal design for many years, and it was considered unlikely that this program could produce a product better than any urinal already produced.

The urinal selected was a Rexall Drug Company pure gum rubber male urinal, Figure 4. It consists of an outer chamber and a replaceable inner seal. The seal is tapered and must be trimmed to fit the penis of the subject. It acts to keep urine in the outer chamber from coming in contact with body parts. The urinal is fastened to the body by a strap around the hips and a strap under each leg.

Urinal Connector

Since the suit valve is permanently attached to the suit, a connector, Figure 5, is provided for attachment of the urinal to the suit valve. The design of the connector was made as simple as possible to allow for maximum flow with the smallest outside diameter. It is fabricated of aluminum, and is threaded so that it may be engaged simply by screwing the mating parts together.

Suit Valve

The heart of the system is the suit valve, Figures 6 and 7. Removal of urine from the suit is predicated on a differential pressure between the suit and ambient air. The urinal will, of course, collapse on the penis after all urine has been forced out of the suit. This will cause pressure on the penis which may be painful when the suit is pressurized at an operating pressure of 5 psi. Therefore, a path must be provided to allow suit air back into the urinal. Provisions for this were incorporated in the suit valve through the small holes, Figure 7-(1). These holes are sealed off to prevent urine escaping into the suit by an "O" ring seal, Figure 7-(2). This seal will allow for a small amount of air leakage during urination, which will aspirate the last urine out of the valve after the urinal has collapsed and mechanical pressure of the system no longer acts on it. Urine will be exhausted from the urinal through the valve inlet, Figure 7-(3), through the holes in the valve tube, Figure 7-(4), and the valve tube, Figure 7-(5).

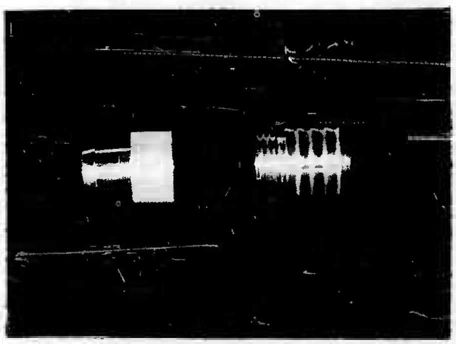

Figure 5. Urinal Connector

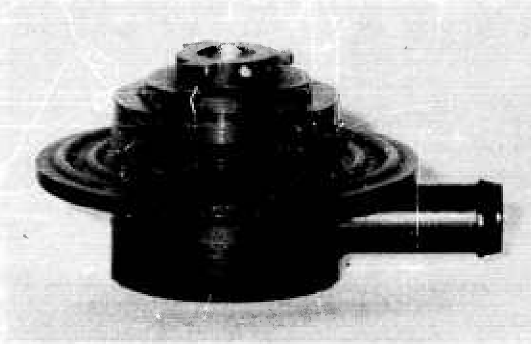

Figure 6. Suit Valve

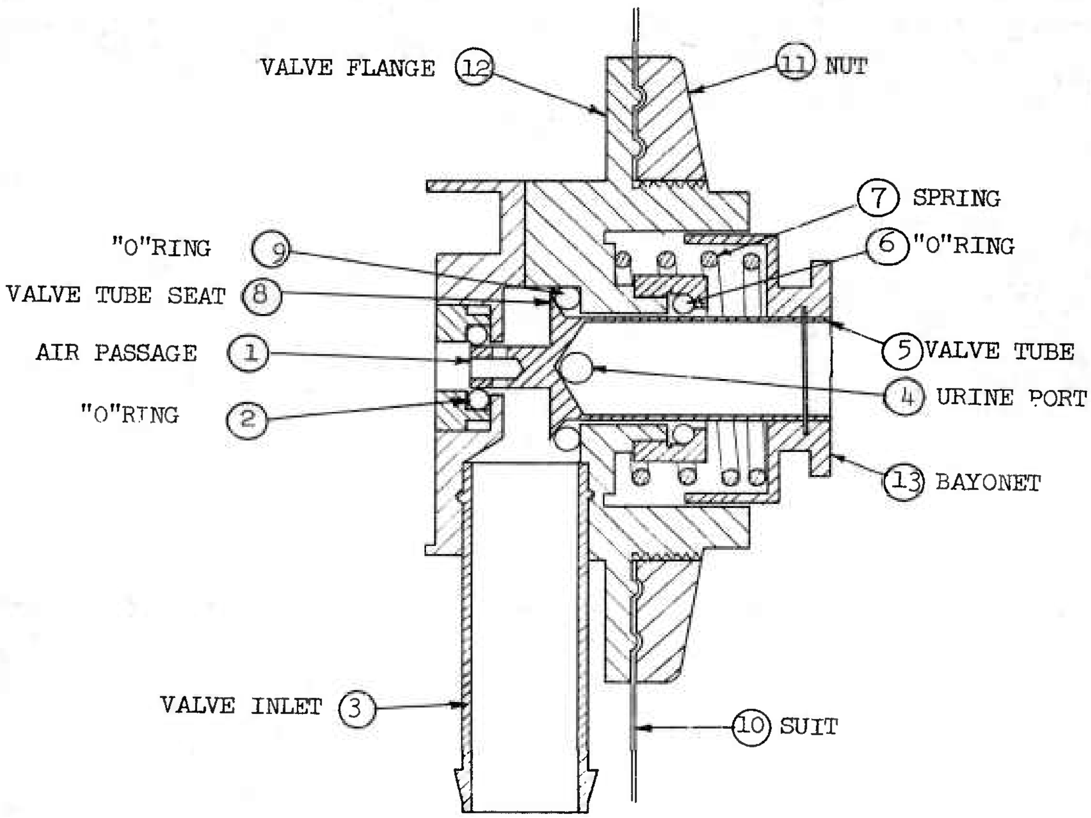

Figure 7. Suit Valve Diagram

Urine is prevented from escaping into the cabin by an "O" ring, Figure 7-(6). When released, the tube is moved to closed position by spring, Figure 7-(7). The entire system is then sealed to prevent suit leakage by the seating of the tube seat, Figure 7-(8), against the sealing "O" ring, Figure 7-(9). The valve itself is attached to the suit, Figure 7-(10), by the clamping action of the nut, Figure 7-(11), against the valve flange, Figure 7-(12). The flange and nut are grooved to prevent slippage and provide an air-tight seal with the suit.

In the event of an emergency during urination, the valve is released by the subject, and then is closed automatically by the spring. A small amount of urine still in the urinal and valve will be forced into the suit through the vent holes, Figure 7-(1), because of its inertia. The remainder will remain in the urinal and valve, and can be released by again opening suit valve when the emergency has passed.

Suit Valve Connector

The suit valve connector, Figure 8, is attached to the urine collection bag connector by a collapsible vinyl tube, and is connected to the suit valve prior to urination by the bayonet lock, Figure 8-(1). A urine seal is provided, Figure 8-(2), which is forced against the bayonet connection on the suit valve, Figure 7-(13). The connector has a large flat surface, Figure 8-(3), for ease of operation by a subject encased in a space suit. The suit valve is opened by depressing the connector.

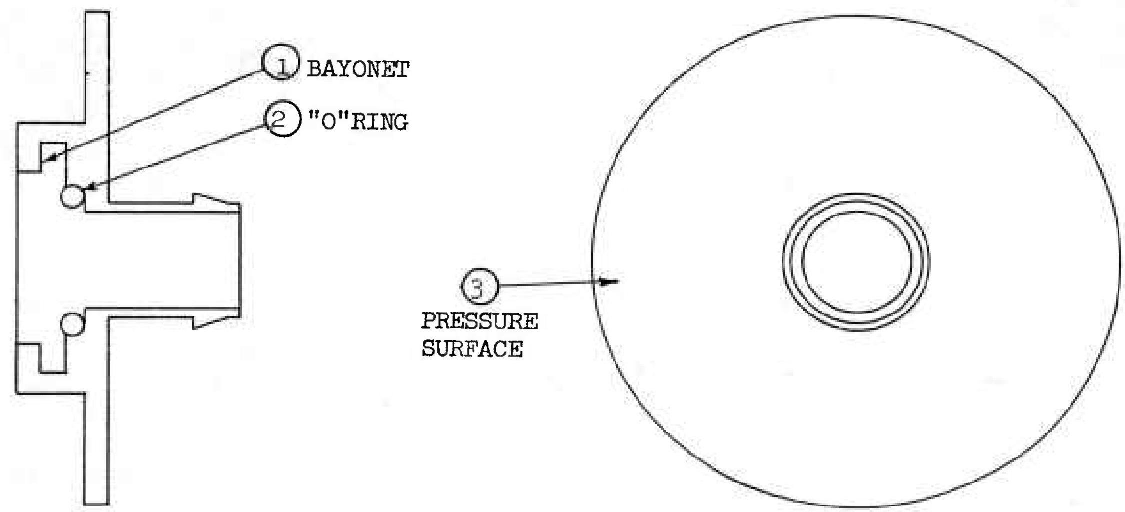

Figure 8. Suit Valve Connector

Collecting Bag, Valving and Sampling

The urine exhausted from the suit, through the suit valve, flows through the vinyl tube and inlet valve, Figure 9, into the collecting bag. The inlet valve is a check valve to prevent urine in the bag from flowing back toward the suit valve when the bag is being emptied. Because of the zero gravity and corrosion problems, no conventional gravity or spring-controlled check valve is usable. The valve employed consists of a rubber disk, Figure 9-(1), which will allow urine to pass to the direction indicated in Figure 9, but will seal against the valve seat, Figure 9-(2), when pressure is applied to the reverse side.

Once inside the collection bag, the urine may be sampled for urinalysis before disposal. The sampling vial must be removed after each urination; therefore, it is a source of leakage. A valve had to be designed to have a positive cut-off at separation, since conventional no-drip valves depend on gravity to carry away the liquid. Provisions also had to be made for exhausting air from the vial. Again, zero gravity had to be considered since the liquid will not displace the air in a manner that will allow simply siphoning of the air from the top of vial. In order to accomplish this, the sample valve and vial, Figure 10, was devised. It consists of a rubber slide, Figure 10-(1), two needles (somewhat similar to those used to inflate a football, Figure 10-(2) and Figure 10-(3), and associated bayonet, Figure 10-(4), and sleeve, Figure 10-(5). When not in use, the needles are sealed by the pressure of the rubber slide. The sample vial is a polyethylene tube permanently closed at one end and covered with a rubber disk at the other end, Figure 10-(6). It has a connection, Figure 10-(7), which mates with the valve in one position only. The rubber disk is punctured to allow the needles to pass through without damage while still providing a water-tight seal. A tube, Figure 10-(8), extends from beneath one of the perforations to a point near the bottom of the vial.

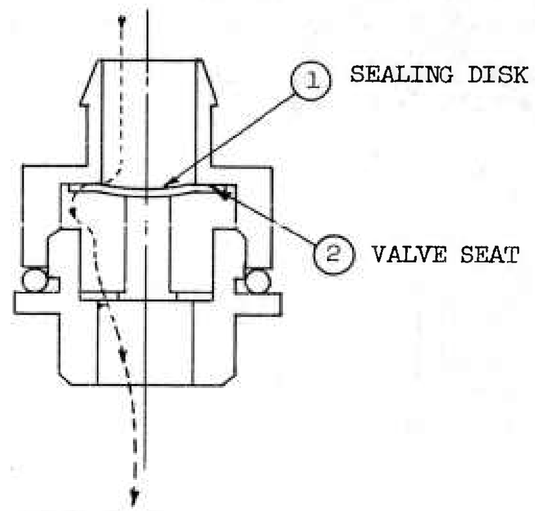

Figure 9. Inlet Valve

In order to obtain a sample of urine, the vial is inserted into the sample valve and turned $\frac{1}{4}$ turn. This aligns the perforations in the rubber disk with the needles. The vial is then depressed forcing the rubber slide back and the needles into the vial. The collection bag is then squeezed manually forcing urine out of needle (2) into the vial. Air in the vial will be displaced by the urine and can escape through the vial tube, needle (3), and the tube, Figure 12-(1), in the collection bag, to a chamber provided in the top of the bag, Figure 12-(2). The sample will be limited to the quantity of urine that displaces the air before urine is ejected through the air escape tube.

When the sample is taken, the vial is manually pulled away from the valve. This returns the rubber slide to its closed position, thus sealing the valve. At this time,

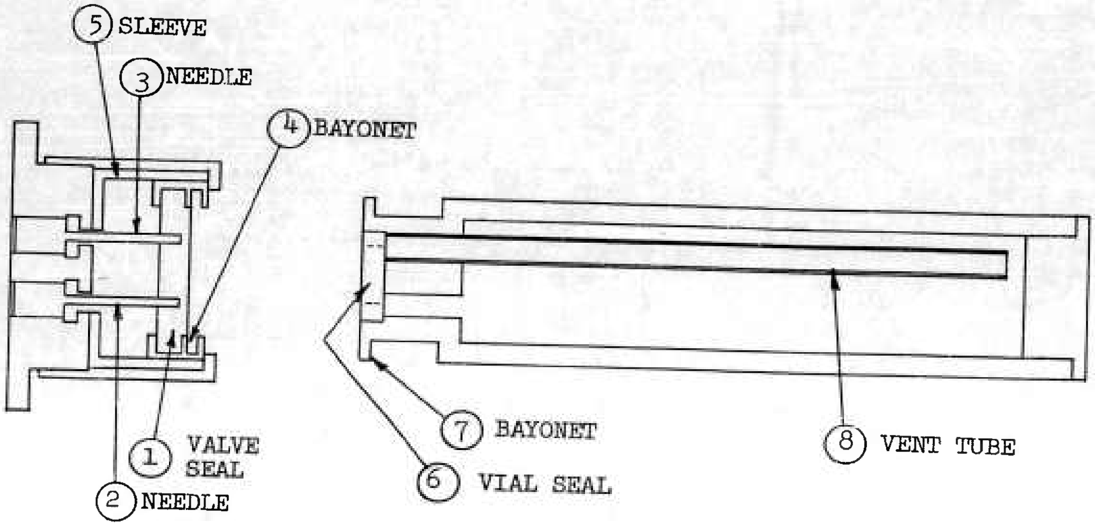

Figure 10. Sample Valve and Vial

the vial can be turned to release the bayonet and removed from the valve for storage. The vial cannot be turned to the unlocked position during sample taking because of the needles inserted through the rubber disk.

The exhaust valve, Figure 11, is a simple slide valve. The urine is retained by the seals, Figure 11-(1), and Figure 11-(2), when the valve is closed. When opened, the slide is moved to position indicated and urine is allowed to flow past seal (2) to the exit port of the valve. External leakage is prevented by seals (1) and (3). This valve is manually operated and should be kept open until the vehicle is in orbit in order to allow for pressure equalization between the collection bag and ambient air.

A threaded hole is provided on the exit port of the exhaust valve for connection to the urine recovery system, or the outside of the vehicle, depending upon the final disposition of the urine.

The collection bag, Figure 12, consists of a two-chamber vinyl container. Urine is collected in the lower chamber, Figure 12-(3), and air from the exhaust of the sample vial is collected through a tube, Figure 12-(1), in the upper chamber, Figure 12-(2). Urine fills the lower chamber during and immediately after urination through the inlet valve, Figure 9, and is retained there by the closed sample valve, exhaust valve, and the checking action of the inlet valve. When the sample is taken, air from the sample vial enters the upper chamber. The urine remaining in the lower chamber is removed by opening the exhaust valve and collapsing the collection bag manually. This is accomplished by rolling the bag from the top toward the valve housing. This can be done at any time prior to the next urination, since, if a recovery system is used, it may not be ready to accept the urine immediately

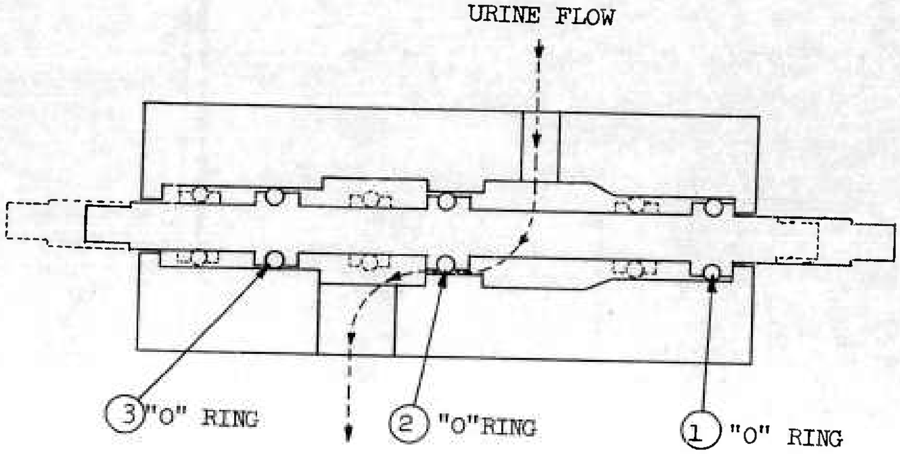

Figure 11. Exhaust Valve

after each urination. The air collected in the upper chamber can be released to the lower chamber through a check valve, Figure 12-(4), in the chamber dividing wall before or after the urine has been forced from the bag.

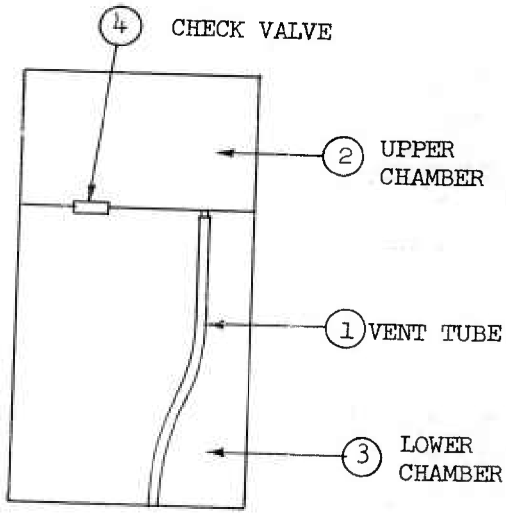

Figure 12. Collection Bag

The valve housing, Figure 13, is attached to the bag and sealed against leakage with a plate, Figure 14. The plate contains five "O" rings to assure a water-tight seal.

Container

The container in which the sample vials and collection bag are to be stored was not designed, since the dimensions are dependent upon space available in the vehicle selected for use.

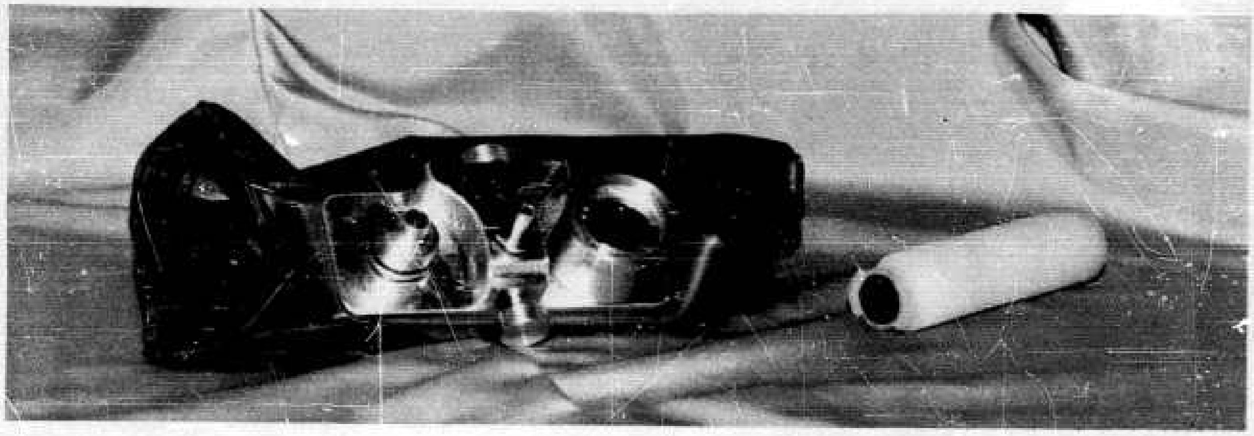

Figure 13. Collection Bag Valve Assembled to Test Bag, With Sample Vial Not Attached

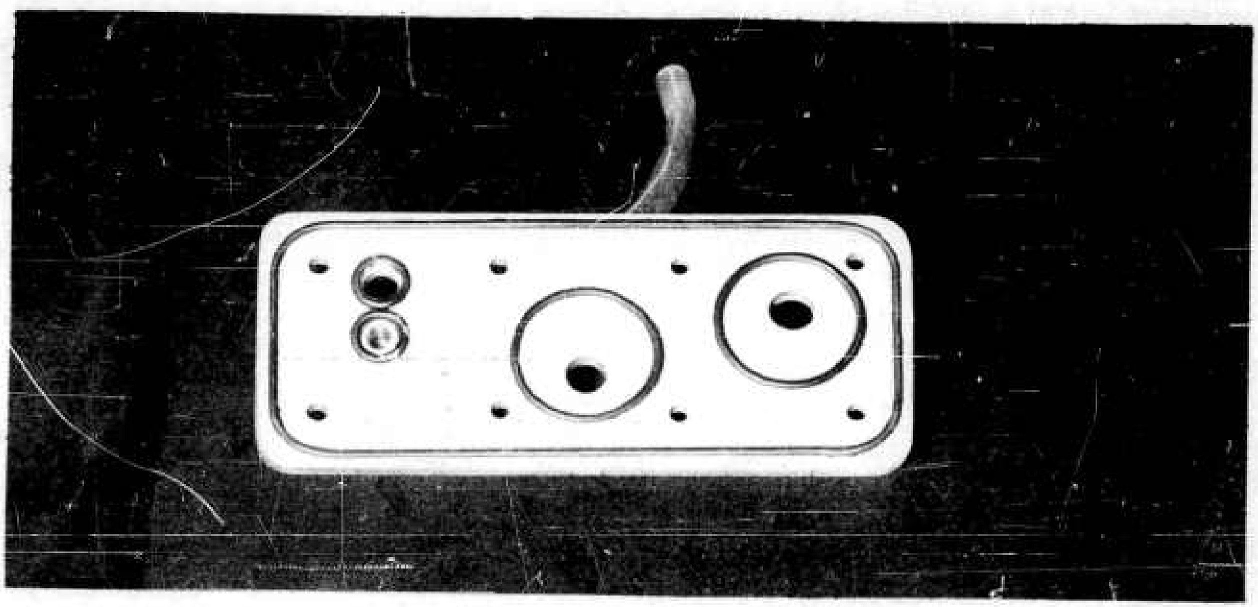

Figure 14. Sealing Plate For Collection Bag Valve

SECTION 3

TESTING PROGRAM

Objectives

The testing program was carried out to determine the compliance of the system with the operational requirements set forth in the contract, and the performance characteristics deemed necessary for successful operation of the system based upon the specific design features employed.

Compliance tests included:

1. Flow rate.
2. Comfort and compatibility.
3. Resistance to urine.
4. Leakage.

Other tests included:

1. Ability to withstand changes in pressure without damage
2. Liquid transfer to sample vial.
3. Operation of inlet check valve.
4. Air leakage into the system.

Difficulties Encountered

The major difficulty encountered in the testing program was the inability to produce or simulate the condition of weightlessness. This did not present a problem in testing compatibility of the urinal and suit valve with the suit, or the flow rate and operation of the suit valve. In testing the collection bag and sampling system, however, it presented an insurmountable problem since there is air and water present in the collection bag at all times. No matter which direction the bag is held, the air and water must separate, and in a weightlessness condition they cannot be separated. Even the short periods of weightlessness attainable in aircraft will not allow for adequate testing since the time involved in performing the tests far exceeds the periods of weightlessness.

Test Equipment

Several of the tests required no test equipment, other than the collection system itself. Other equipment used is as follows:

1. Pressure Suit
2. Camera
3. Vacuum Chamber

4. Manometers
5. Stop Watch
6. Urine and Container
7. Pressure Chamber
8. Vacuum Pump
9. Compressed Air
10. Soapy Water

Suit Valve

The suit valve was tested for leaks and flow in the pressure chamber, Figure 15. With the valve installed, the chamber was inflated to $\frac{1}{2}$, 5 and 10 psi, and checked

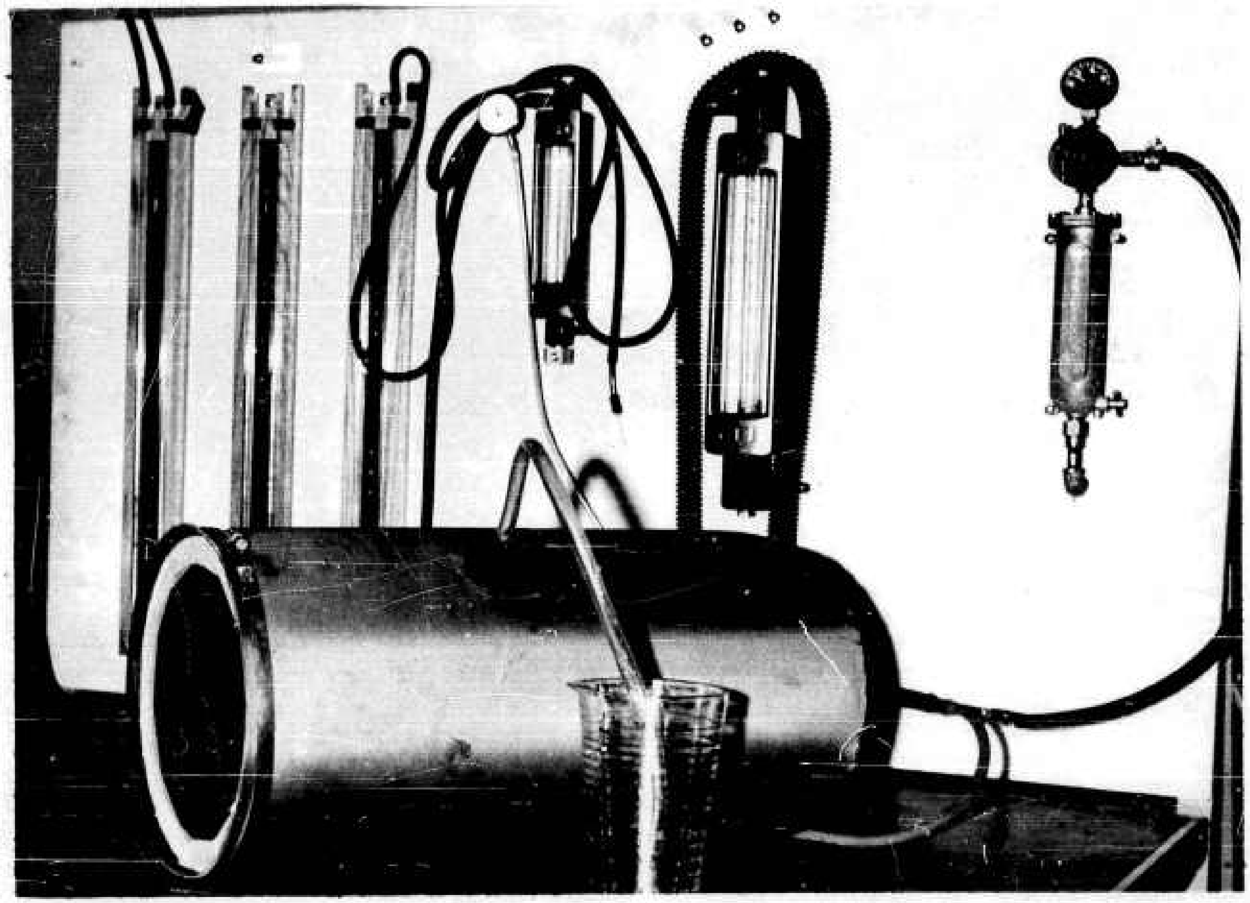

Figure 15. Flow Test Apparatus

for leaks with soapy water. None were found. Figure 16 depicts the arrangement of the chamber for the flow tests. These tests were run against gravity in all cases, thus, putting a penalty on the flows obtained. The results of these tests are tabulated in Tables 1 and 2. Table 1 represents test performed on the first suit valve and fabricated. It is obvious from Table 1, that the flow rate could not be attained with valve #1. Therefore, a second suit valve was designed. Excessive air leakage was noted in the first model, and steps were taken to alleviate this condition in the second model. The test performed by filling the bladder, Figure 16-(1), with a measured amount of water, connecting the bladder to the valve, Figure 16-(2), and closing the end of the chamber with a plexiglas plug in order to observe the valve for water leakage during operation (in no case was leakage observed.). Compressed air was put into the chamber and measured with a manometer, Figure 16-(3). When the chamber reached the test pressure, the suit valve was opened and the time to empty the bladder recorded.

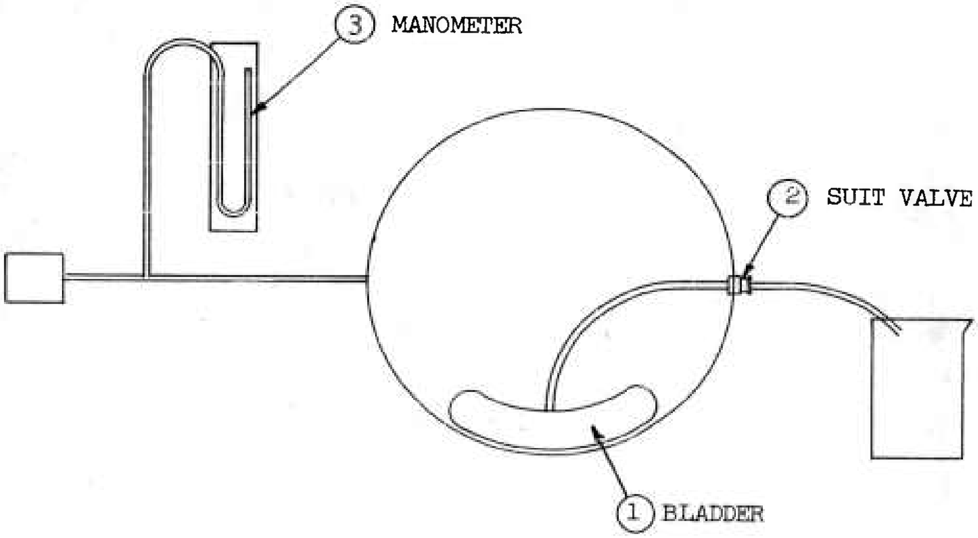

Figure 16. Flow Test Apparatus

Comfort and Compatibility

The urinal and suit valve were tested for comfort and compatibility by donning the urinal with the ILC space suit. The subject went through the various body motions, i.e., sitting, standing, climbing, and leg movement, Figure 17, without difficulty, and reported that he could not tell he had the urinal on after the suit was brought to vent pressure.

The urinal was found to lead down the crotch into the left leg, Figure 18. The urinal and tube had no pressure whatsoever exerted upon them by the suit. The suit valve did not touch the subject's leg at vent pressure, but moved back against it when opened. At higher pressure, the valve did not touch his legs.

No difficulty was experienced in donning or doffing the suit.

TABLE 1

FLOW RATE SUIT VALVE-MODEL #1

Pressure (PSI)	Quantity of Water (Liters)	Time to Empty (Minutes)	Flow (Liter/Minute)
0.5	1	7	.143
1	1	5	.2
2	1	3	.333
3	1	2	.50
4	1	1.75	.573
5	1	1.83	.543

TABLE 2

FLOW RATE SUIT VALVE-MODEL #2

Pressure (PSI)	Quantity of Water (Liters)	Time to Empty (Minutes)	Flow (Liter/Minute)
0.5	0.9	1.42	0.635
1	0.9	1.0	0.900
2	0.9	0.75	1.200
3	0.9	0.42	2.142
4	0.9	0.32	2.810
5	0.9	0.25	3.600

Figure 17. Test Subject Demonstrating Mobility While Pressurized With Urinal in Place

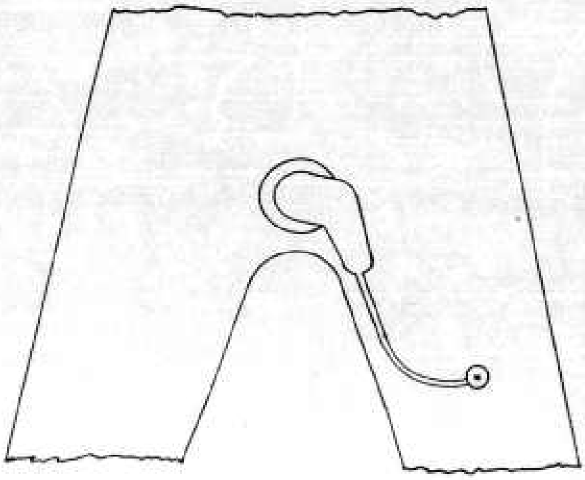

Figure 18. Position of Urinal in Suit

Resistance to Urine

The metal components were tested for resistance to urine by soaking bars of each material used in urine for two weeks. The samples were removed periodically and allowed to air dry. At the end of the test period they were dried, rinsed off, and examined for damage. None was found.

Leakage

Leakage of air through and around the suit valve was checked during the flow test. The valve was tested with soapy water at each pressure. The first valve was found to have several leaks. The cause was located and provisions made in the second model to eliminate them. The second model had no leakage when tested.

Water leakage in the collection bag and valves was checked by assembling the unit and applying mechanical pressure on the bag. No signs of leakage were noted with the valve properly assembled.

Pressure Change

The suit valve and urinal will not be affected by the drop in pressure resulting from leaving the atmosphere for extraterrestrial flight, since there is provision for pressure equalization built into the valve. Pressure compensation for the collection bag can be obtained by opening the exhaust port during take-off.

The sample vials, however, have no built-in safety features to allow for pressure equalization. Their behavior, under conditions of decreasing and increasing ambient pressure, was determined by placing a sample vial in a vacuum chamber and exhausting the air. The cycle was repeated 5 times with no damage to the vial.

Liquid Transfer to the Sample Vial

This test cannot be adequately performed in the presence of gravity. The vial is designed to work at zero gravity, thus contains design features that severely penalize when tested with or against gravity. The test was performed with the vial inverted so that the liquid was forced into the vial against gravity. Difficulty was encountered here because the water in the bag fell to the bottom of the bag leaving only air in contact with the valve. Thus, care had to be exercised to assure a bag completely full of water was used. The inlet check valve had to be plugged to prevent air leakage into the bag. Using this method of testing, the vial can be filled until water enters the air return tube.

Operation of the Inlet Check Valve

The bag was filled for the leakage and liquid transfer tests through the inlet check valve without difficulty. Its ability to prevent back flow was checked as a part of the overall leakage test. It was found that, if extreme mechanical pressure is put on this bag, a few drops of liquid can be forced back through the valve. The amount was not, however, great enough to affect the satisfactory operation of the check valve in the system.

Air Leakage Into the System

Leakage of air from the suit into the collection bag was determined with the same apparatus used to determine flow. The volume of air was found to be not over 10% of the total volume of air and water in the bag. Some of this air, of course, was in the tubes before the test began. Additional air will enter the bag if the valve is left open after the water has been exhausted from the interior of the pressure chamber. The test was performed under normal ambient pressure conditions and should be checked in a walk-in vacuum chamber.

Summary of Test Results

Test results obtained within the limits imposed by the normal gravitational field, indicate that the system will satisfactorily provide for the evacuation and handling of urine from a man wearing a full pressure garment.

SECTION 4

CONCLUSIONS

The following were deduced from testing the system:

1. The urinal and suit valve are compatible with a full pressure suit.
2. The materials used are not affected by urine.
3. The urinal is comfortable.
4. The system will not introduce air leaks into the suit.
5. The system can be adequately tested only under weightless conditions and low ambient pressures. Present test aircraft do not provide sufficient time for the test.

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International Latex Corporation, Dover Delaware
URINE COLLECTION AND DISPOSAL DEVICE FOR PRESSURE SUIT, by Robert J. Redden. August 1961. 26 pp. incl. illus., tables. (Project 7164; Task 71831) (Contract AF 33(616)-7344)
Unclassified report

The design, fabrication, and testing of a urine collection and disposal system, to provide a means to remove urine from within a full pressure suit during long periods of use, in a weightless environment, and to provide a means of sampling each individual specimen of urine, are discussed. The prototype

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III. Contr. AF 33(616)-7344

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The design, fabrication, and testing of a urine collection and disposal system, to provide a means to remove urine from within a full pressure suit during long periods of use, in a weightless environment, and to provide a means of sampling each individual specimen of urine, are discussed. The prototype

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